STUDSVIK PROCESSING FACILITY UPDATE

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ABSTRACT

Studsvik has completed its first full year of operation at its Erwin TN facility. During the year Studsvik carried out an extensive program to bring the facility systems to their original design specifications and processed over 23,000 cu. ft. of radioactive charcoal, bead and powdered ion exchange resins.

The Studsvik Processing Facility (SPF) has the capability to safely and efficiently receive and process a wide variety of solid and liquid LLRW streams including: ion exchange resins (IER), charcoal, graphite, sludge, oils, solvents, and cleaning solutions with contact radiation levels of up to 2.0 Sv/h (200 R/hr). The licensed and heavily shielded SPF can receive and process liquid and solid LLRWs with high water and/or organic content.

The SPF employs the THermal Organic Reduction (THOR^{sm}) process, developed and patented by Studsvik, which utilizes pyrolysis/steam reforming technology. THOR^{sm} reliably and safely processes a wide variety of LLRWs in a unique, moderate temperature, pyrolysis/reforming, fluidized bed treatment system. The THOR^{sm} technology is suitable for processing hazardous, mixed and dry active LLRW (DAW) with appropriate licensing and waste feed modifications.

Operations have demonstrated consistent, reliable, robust operating characteristics. A wide variation of processing efficiencies and ultimate volume reductions have been experienced due to the widely varying characteristics of the incoming waste streams. Input waste has varied in total inorganic content, the determining factor for volume reduction, from <1% to greater than 70%. A substantial element of this variability has been the "soluble salt" content of the input waste streams that has been found to vary from < 1% to greater than 20% of the input waste material.

Final reformed residue comprises a non-dispersible, granular solid suitable for long-term storage or direct burial in a qualified container. THOR^{sm} effectively converts hexavalent chromium to non-hazardous trivalent chromium and can convert nitrates, if present, to nitrogen with over 99 percent efficiency in a single pass.

This paper provides an overview of the first full year of commercial operations processing radioactive ion exchange resins from commercial nuclear power plants. Process improvements and lessons learned will be discussed.

PROCESS OVERVIEW

Since 1947 Studsvik has been actively involved as a research center for nuclear power in Sweden. Studsvik operates a research test reactor and hot cell facility for production of medical isotopes, commercial nuclear fuel testing, and materials irradiation. Studsvik operates a Dry Active Waste (DAW) incinerator, which has been in commercial operation since the early 1970s. Full metal melting and recycling capabilities for carbon and stainless steels and aluminum have been in use for several years.

The THOR[sm] process utilizes two fluid bed contactors to process a wide variety of solid and liquid LLRWs. Figure 1 provides an overview flow diagram of the THOR[sm] process. Radioactive waste feeds are received at the SPF and stored in holdup tanks. As waste is needed in the process, waste is transferred to the waste feed tanks for metering and injection into the first stage fluid bed pyrolyzer/reformer. Solid, dry, granular wastes such as charcoal, graphite, soil, etc are metered into the pyrolyzer by the solids feeder. Liquids and slurry wastes such as IER, sludges, oils, antifreeze, solvents, cleaning solutions, etc are metered into the pyrolyzer by a pump.

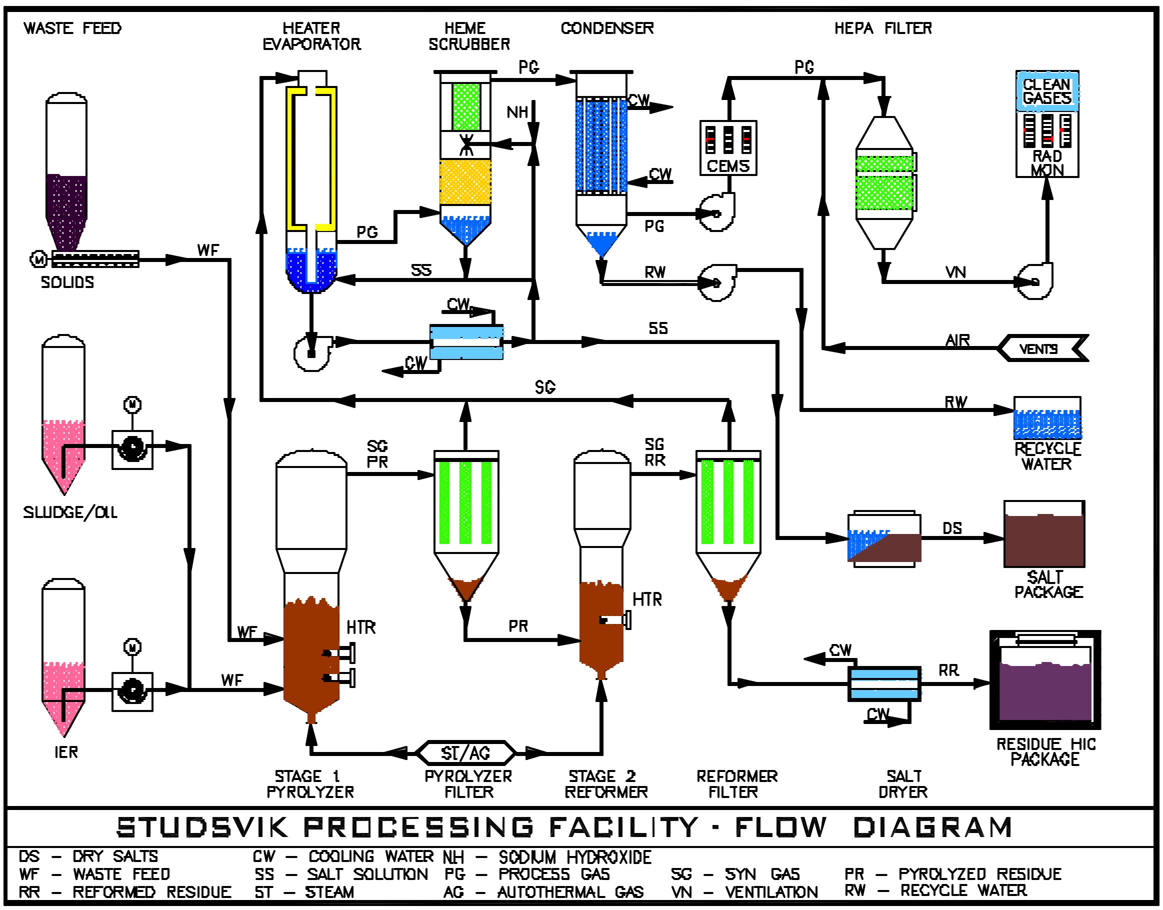

Fig. 1. THOR[sm] Process Flow Diagram

The pyrolyzer fluid bed serves to evaporate all water from the IER slurry and liquid waste feeds, and pyrolyzes the organic components through destructive distillation. Fluidizing gases, volatile organic vapors, and steam released in the pyrolyzer fluid bed comprise a synthesis gas, which passes through the ceramic filters and to the gas handling system. The low-carbon, metal oxide-rich residue removed by the ceramic filter can be further processed in the second stage steam reformer to remove any final carbon or to convert the oxidation state of selected metals. The stage 2 Reformer can also be used as a primary waste processing unit by the direct injection of liquid wastes. The radioactive, volume reduced residue is packaged in qualified high integrity containers for burial at licensed burial sites or return to the generator.

Through selection of autothermal steam reforming operating conditions it is possible to produce an inert, inorganic final waste that consists of only the radioactive elements, metal oxides and inorganic calcium and silica compounds initially absorbed on the IER. Another significant improvement realized by the THOR^{sm} process is the ability to process wastes with high water content. Aqueous wastes do not need to be dried prior to processing, but can be injected directly into the fluid bed using reliable slurry pumping equipment. Sodium nitrate slurry, oils, activated carbon, antifreeze solution, steam generator cleaning solvent and several types of IERs have all been successfully processed by the THOR^{sm} process.

STUDSVIK PROCESSING FACILITY

Studsvik has completed its first year of full commercial operation. Commercial operation of the Studsvik Processing Facility (SPF) began in July 1999 with limited operations as the plant was brought up to capacity. The SPF and THOR^{sm} process systems are described below. The SPF is designed to meet all laws, codes, and standards related to processing LLRW. A photograph of the SPF is shown in Fig. 2.

Fig. 2. SPF Overview

The SPF is designed to meet the following criteria:

- Facility Curie Inventory: up to 2,000 Ci (74 TBq)
- LLRW Input Curies: up to 2.0 Ci/cu.ft. (2.6 TBq/m^3) Contact dose of up to 200 R/h (2.0 Sv/h)
- LLRW Inputs: Ion Exchange Resins, Charcoal, Graphite, Organic Solvents and Oils, Aqueous Decon and Cleaning Solutions, Slurries, and Sludge

The SPF consists of a heavily shielded Process Building, unshielded Ancillary Building, and an Administration Building. The Process and Ancillary Buildings are licensed for receipt, handling, processing, and packaging of LLRW.

Process Building

The Process Building contains all radioactive processing, handling, and packaging systems for volume and weight reduction of incoming LLRW. Major areas include truckbays, LLRW input holding tank vault, pyrolysis/reforming vault, gas handling vault, salt dryer room, final residue packaging vault, and auxiliary equipment rooms.

Truckbays

LLRW is shipped to the SPF in unshielded containers or shielded casks qualified by DOT or NRC. Most LLRW is received in the truckbays where containers and casks are surveyed, opened and the waste transferred to shielded waste input holding tanks located in shielded vaults. Cask maintenance activities are performed in the truckbays where an overhead bridge crane provides lifting capability.

Waste Input Holding Tanks

Three large stainless steel slurry holding tanks are provided for receipt and holdup of incoming liquid and slurry wastes. A separate liquid waste tank is used to receive more volatile organic solvents, cleaning solutions, and oils. A lockhopper feeder is used to receive and feed granular and powdered LLRW, such as charcoal. A separate waste feed tank with injection pumps is used to meter slurry and liquid wastes from the slurry holding tanks into the stage one pyrolysis vessel.

Pyrolysis/Reforming System

The Pyrolysis/Reforming THOR^{sm} system comprises: stage one pyrolysis contactor (pyrolyzer), stage two reformer contactor and associated filters. The pyrolyzer is a vertical, cylindrical flu id bed gasifier designed to operate at up to 800^{o}C. LLRW is injected into the electrically heated, fluidized pyrolyzer where: 1) water is instantly vaporized and superheated, and 2) organic compounds are destroyed as organic bonds are broken and resulting synthesis gas (principally carbon dioxide, carbon monoxide, and steam) exits the Pyrolyzer. Residual solids from the pyrolysis of the LLRW (including fixed carbon, >99.8 percent of the incoming radionuclides, metal oxides and other inorganics and debris present in the LLRW feed) are removed from the pyrolyzer and collected in the stage one ceramic filter vessels. The pyrolyzer is fluidized with superheated steam and additive gas. Figure 3 is a photograph of the reformer process area.

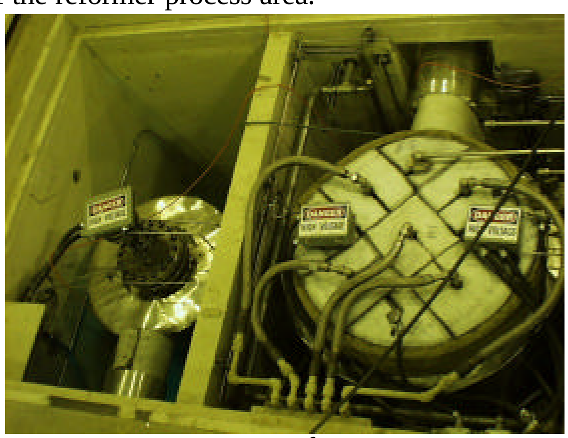

Fig. 3. Process Area - Reformer

The stage two reforming contactor is a vertical, cylindrical fluid bed designed to operate at up to 800^{o}C. Pyrolyzed solid residues from the stage one filters or additional LLRW feed can be transferred to the reformer, which is an electrically heated, fluidized bed. The reformed, low-carbon, final residue is collected in the stage two ceramic filter vessel. The reformer is fluidized with superheated steam and additive gas.

Gas Handling System

The gas handling system comprises an energy recovery heater, submerged bed evaporator, scrubber/mist eliminator, condenser, CEMS, process blower, HEPA filter, vent blower and radiation monitor. The purpose of the gas handling system is to convert synthesis gas constituents to carbon dioxide and water, recover energy from the synthesis gas, convert acid gases to stable salts, control water content of exiting process gases, and control negative pressure levels throughout the THOR^{sm} pyrolysis/reformer system.

Synthesis gases from the pyrolyzer and reformer are filtered and then oxidized in the energy recovery heater to carbon dioxide and water. The heater recovers energy from the synthesis gas and provides heat to the submerged bed evaporator where excess water is evaporated from the scrubber water. The heater is a vertical, refractory lined vessel that operates at up to 1200°C.

The submerged bed evaporator is an energy recovery system that channels the hot heater outlet gases through a volume of scrubber water, thereby evaporating excess water. The evaporator concentrates scrubber solution to 10 to 20 percent salts. The wet evaporator gases pass through the rotary atomizer scrubber where sulfur and halogen gases are efficiently converted to salts. Sodium hydroxide is metered into the scrubber to neutralize sulfur and halogen gases that are absorbed by the scrubber solution. The outlet of the scrubber is fitted with a mist eliminator that removes particulates and mists from the scrubber outlet.

The clean, moisture-laden gases exit the scrubber and excess moisture is condensed for recycle/reuse in the process. The condenser serves as the process heat sink and serves to control water balance in the SPF. The cool, clean gases are then compressed to atmospheric pressure by the process blower. A continuous emissions monitoring system (CEMs) is provided on the process blower outlet to monitor and record the release of any traces of carbon monoxide, acid gases, total hydrocarbons, and NOx.

The clean, cool process gases commingle with the building ventilation airflow. The combined gases flow through a HEPA filter bank, vent blower and are then released through a monitored vent stack. A complete radiation monitor system measures and documents any trace radionuclides that may pass through the stack. The radiation monitor system includes gamma, beta, alpha, iodine, carbon^{14}, and tritium samplers and detectors.

Salt Handling System

The salts that are formed in the scrubber and concentrated in the evaporator are transferred to the salt handling system, which comprises a filter, an ion exchange system and to one of two salt dryer systems, a steam heated rotary drum and a spray dryer. The concentrated salt solution is filtered to remove any trace particulates that may pass through the pyrolyzer and reformer filters. Any trace radioactive species are removed from the scrubber solution by a high-efficiency, metals selective ion exchange medium. The salt dryer dries the purified salt solution to form a salt cake suitable for direct disposal. The dry salt is very low in activity.

Residue Handling System

The reformed, low-carbon residue from the pyrolyzer and reformer is transferred to the high integrity container (HIC) packaging vault. Qualified HICs are filled with the solid, inert residue. Filled HICs are transferred from the packaging vault to a shipping cask be means of a shielded transfer bell. Dual containment and seals are provided on residue handling components. The packaging vault is provided with separate HEPA filtered ventilation system and water washdown capability.

The HIC packaged residue is suitable for direct burial at either the licensed Barnwell or Hanford LLRW burial sites. The packaged residue is also suitable for long-term storage due to its solid, inert, all inorganic nature.

Waste Form Improvement

The thermal processing alleviates many of the concerns with the long term storage or shallow land disposal of ion exchange resins.

- Organic materials are destroyed thus eliminating the generation of flammable gases from biological attack and/or radiolysis.
- "Foreign chemicals" have been destroyed that could react with packaged waste and generate undesirable reactions. Thus the potential for damage to waste packages, which could promote radionuclide migration is removed.
- Volume is reduced yielding a small sized source term for storage, disposal and/or long-term monitoring and the overall waste form is improved to enhance environmental protection.

An additional benefit of the thermal processing of the ion exchange resins is that the tritium and C-14 fraction of the waste is removed. Thus, one of the major concerns for shallow land disposal, these long half-life radionuclides, is alleviated.

Spill Protection and Contamination Control

All interior surfaces of the SPF are provided with durable, easy-to-decon coatings. The interior wall and roof panels are of interlocking and sealed construction to eliminate leakage paths from the inside of the SPF to the outdoors. Interior concrete and steel surfaces have a special multi-layer coating to prevent migration of spills or contaminants from the SPF to the environment. The HVAC system also maintains the inside of the SPF at a slight negative pressure relative to the ambient outdoors, effectively eliminating potential airborne releases. Dikes, berms and sumps are located so as to prevent tank leaks and even potential large firewater events from escaping to the outdoor environment.

Auxiliary Equipment and Utility Services

The Process Building contains all auxiliary and utility subsystems required to support SPF operations and THOR^{sm} operations including:

Steam Supply	Sluice Water	Service Air
Nitrogen Supply	Steam Superheaters	Demineralized Water
Steam Condensate	Potable Water	Breathing Air
Instrument Air	HVAC and Ductwork	Dryer Condensate
Natural Gas Supply	Cooling Water	
Additive Gas	Motor Control Center	
Hot Laboratory	DAW Compactor	

ANCILLARY BUILDING

The Ancillary Building is designed for storage of spare parts, empty waste shipping containers and equipment for use at customers' locations. A spray dryer and collector are being installed to provide additional salt drying capability for the process. Full salt containers are accumulated for shipment for disposal. Low activity LLRW can also be received and offloaded in the Ancillary Building. Maintenance of plant equipment is also performed in a controlled area. A modular, skid-mounted, pilot-scale THOR^{sm} system can be located in the Ancillary or Process Building to perform testing on surrogate and low activity wastes.

ADMINISTRATION BUILDING

The Administration Building has: offices for plant staff and management, control room, switchgear and UPS, health physics and personnel contamination monitoring areas, and count room. The THOR^{sm} control room provides remote readout of all process parameters. Trained operations personnel utilize the fully automated supervisory control and data acquisition (SCADA) system to monitor and control all system operations. The SCADA provides a comprehensive human-machine-interface that monitors the PLC panels, instruments, and equipment located in the Process and Ancillary Buildings. Automated safety systems, alarms, and interlocks are provided together with real-time data acquisition and trending. The SCADA provides the operators automated flow diagram windows to monitor and control the process through graphical interfaces.

LESSONS LEARNED

The Studsvik Processing Facility commenced limited commercial operations in summer of 1999; however, many of the facility's balance of plant systems designed by the facility's design/build contractor were not capable of achieving their design capacities. This resulted in an extensive ramp-up period. Over the past year, Studsvik has conducted an extensive program to bring the facility to its original specifications. This program is anticipated to be complete later this year.

The following is a partial list of "lessons learned" during the first year of facility operation. It is presented to provide the reader with an understanding of the importance of the support systems for a radioactive waste processing facility.

Resin Transfer Lines – Efficient transfer of resins requires a substantial amount of water to prevent line plugging. When resins are transferred with a vacuum assist, a minor plug quickly dries and forms a significant line blockage. All resin transfer systems must be equipped with numerous backflush and blowdown connections at all points where line plugging can occur.

Resin Filtration – When transferring resins, it is necessary to filter large quantities of sluice water utilized for the transfers. Resins contain fractured resin particles referred to as fines, which sluice water filter systems must be designed with appropriate particle filtration capability to remove. At the same time these systems must have sufficient surface area to insure that the filters don't require excessive backwashing.

Waste Resin Storage - The water-slurried IER is transferred to the slurry holdup tanks where the resins are allowed to settle and excess water is then decanted off the top of the settled resin. Resins of different types have slightly different densities and without adequate storage tank mixing ability, resins will "layer" in a tank. This reduces the ability to efficiently achieve the optimum blend of input waste for processing.

Resin Feed Systems - For efficient thermal processing it is necessary to maintain a constant, relatively low water content in the feed system to the process. Metering of constant resin/water input is a difficult task and specific attention must be paid to design and equipment considerations to insure efficient operations with both bead and powdered resins and mixtures of both.

Off-Gas System – The facility's utilizes a pool type quencher system for quenching and final scrubbing of the hot off-gas from the process system. Impurities, mostly sulfur salts from the cation resins, concentrate in the scrubber solution. The concentrated solution is transferred to a drying system. Care should be taken in equipment design, specification and checkout to insure that systems are operable at design throughput with the actual solution to be dried. Pilot scale test programs on "similar" solutions have proven to be inadequate.

Materials of Construction – With any chemical process system, the materials of construction play a large role in the long-term reliability of the systems. We have encountered an instance where carbon steel was utilized in a high salt environment leading to material failures that have required component replacements.

OPERATIONS SUMMARY

The facility has operated throughout 2000 at approximately 50% of its design throughput due to equipment limitations that are being corrected. (See Lessons learned above.)

Higher activity IER and charcoal have been progressively received and processed. Table I provides a summary of SPF processing throughput and waste processing parameters from the start of commercial operations during the year 2000.

Table I. Year 2000 Processing Throughput and Parameters

Number of input shipments handled	150
Quantity of Radioactive Resin Processed:	>23,000 cuft (>650 cu meter)
Highest Activity Resin Processed:	200 R/h (2 Sv/h) On Contact

CONCLUSION

The Studsvik Processing Facility has demonstrated long-term operation in meeting the waste processing needs of the commercial utilities. We have processed a wide variety of ion exchange resins with widely varying chemical composition and activities. Efforts are in progress to enhance our operational capabilities and to provide more cost-effective waste services in the future.

The THOR^{sm} process, as implemented in the SPF, has the following significant advantages:

- Near Atom-for-atom processing mode is possible
- Inert, inorganic, homogeneous, final waste form
- Direct disposal in qualified HICs
- Accept IER with contact dose rates up to 200 R/h (2.0 Sv/h)

- Accept LLRW including: IER, graphite, charcoal, SGOG solvents, antifreeze, oils, sludge, high-water content wastes, and high-organic content wastes
- Packaged final waste form suitable for long-term storage with no risk of gas generation due to bacterial or radiolysis action (residue has no organic content)
- Final waste form is re-processable to alternative waste forms including vitrification, solidification, encapsulation, cold-sintering, and melting.

Figure 4 provides a summary of potential waste streams that can be processed with the THOR^{sm} technology.

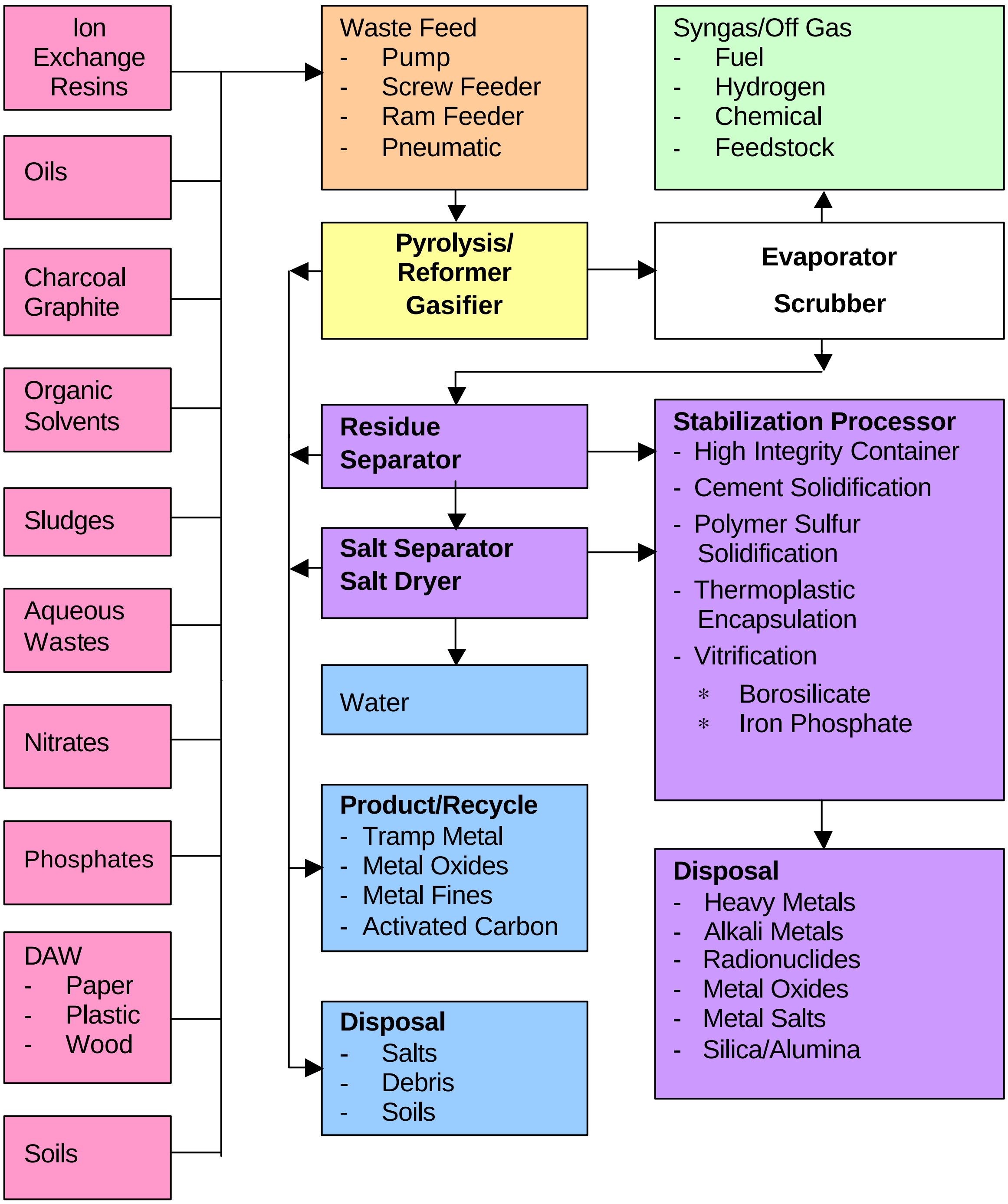

Fig. 4. Block Flow Diagram